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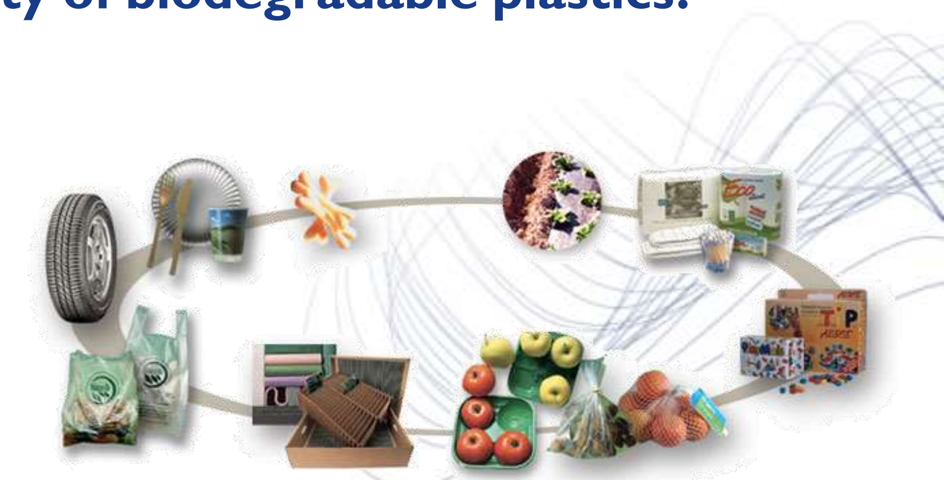
Plastice project

Life cycle assessment of grocery bags

Opportunity of biodegradable plastics?

Mitja Mori

10. 04. 2013



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Agenda

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1. The scope of the study
2. Starting point and methodology
3. Limitations and boundary conditions
4. Inventory analysis
    a. Basic materials
    b. Transport
    c. Production processes
    d. Waste management
5. Gabi 5 numerical models
6. Indicators used in the study
7. Results and analysis
8. Conclusions and recommendations
9. Basic measures

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1.The scope and target audience

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The goal and the scope of the study

- 3 plastic grocery bags (LDPE as basic bag)
- LCA methodology – from CRADLE to GRAVE
- Environmental impact - environmental indicators
- Life cycle of bags – basic scenarios
- Variations in the end of life phase (waste management)

Target audience:

- Bags producers
- Customers
- Waste management companies
- Policy

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2. Starting point of the study

- Functional unit: 1 grocery bag

Type	Description	Manufacturer	Picture	Mass/ gram	Vol. /liter
LDPE	LDPE bag	PLASTA d.o.o. Slovenija		14,8	16,2
PP Life	Long life PP bag – 5 let[1]	Company from Ho Chi Minh City, Vietnam		127	39,6
Mater-BI	Biodegradable and compostable bag[2]	PLASTA d.o.o. Slovenija		20,21*	16,2

- LCA methodology:
  - Gabi 6
  - From cradle to grave

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3. Limitations and boundary conditions

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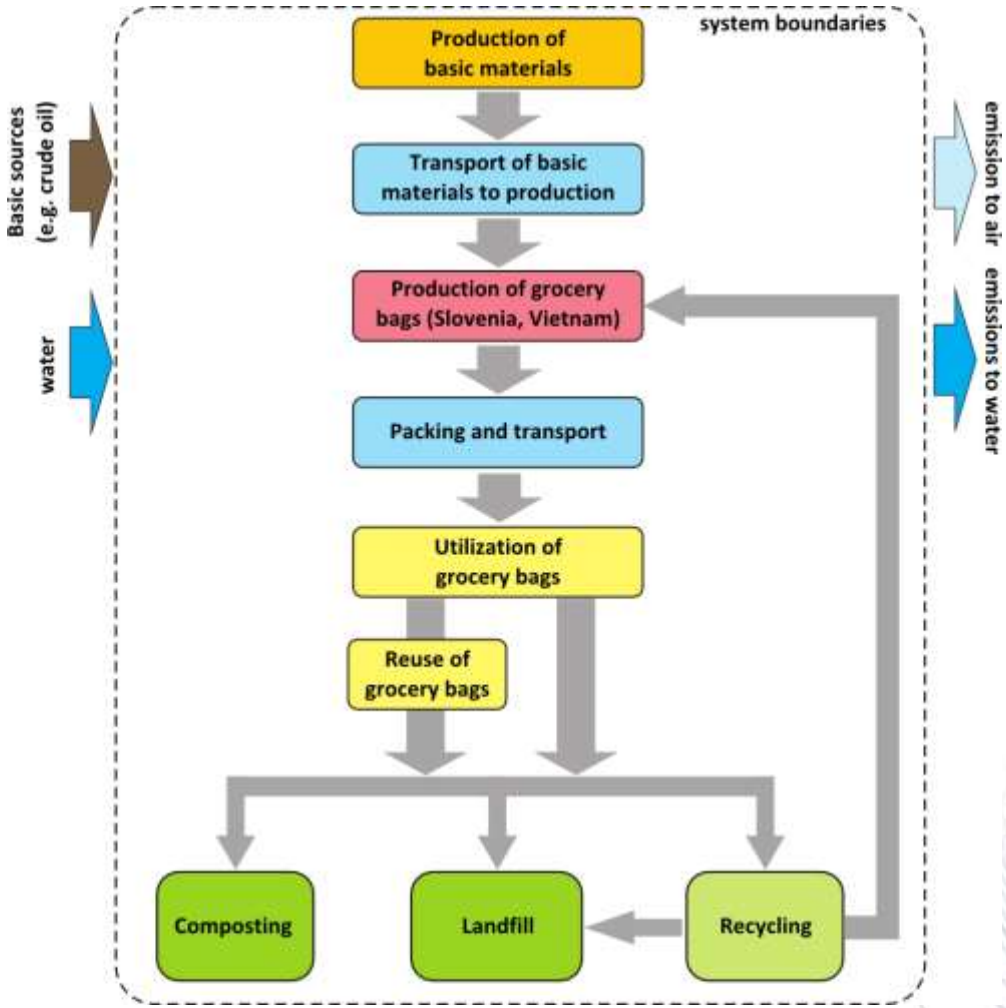

Simple scheme of LCA model

Cut of criteria: Process / Materials

- Production materials
    - TiO2, inks & dies
- Storehouse activity
- Transport:

  store - customers
- Industrial power plants
- Auxiliary materials
- Human labor
- Auxiliary activities

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4. Inventory analysis – basic materials

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Type	Material-basic	Materials / mass		Primary packing
LDPE	Low density polyethylene	LDPE virgin	14,06 g	cardboard 300 g / 500 bags 54 cardboard boxes / 1 EU palete
		titanum oxide	0,592 g	
		TOTAL	14,8 g	
PP-Life	Polypropylene	PP virgin	127 g	cardboard 752 g / 100 bags 14 cardboard boxes / 1 palete
		TOTAL	127 g	
Mater-BI	Mater-BI	Mater-BI	19,80 g	cardboard 300 g / 500 bags 54 cardboard boxes / 1 EU palete
		titanum oxide	0,40 g	
		TOTAL	20,2 g	

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4. Materials: PP vs. LDPE vs. Mater-BI

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	LDPE	PP	MaterBI
Abiotic Depletion (ADP elements) [kg Sb-Eq.]	2,20E-07	4,62E-08	2,08E-02
Acidification Potential (AP) [kg SO2-Eq.]	0,00798	0,00623	0,00919
Eutrophication Potential (EP) [kg Phosphate-Eq.]	0,00050	0,00074	0,00323
Global Warming Potential (GWP 100 years) [kg CO2-Eq.]	2,13	1,99	2,0
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Eq.]	0	0	3,41E-07
Photochemical Ozone Creation Potential (POCP) [kg Eten-Eq.]	0,00121	0,00093	0,00219
Primary energy demand, [MJ]	79,27	75,12	66,0
Water consumption, [kg]	44,9	40,4	233

- 1 kg of virgin granulate
- From cradle to door
- Mater-BI seems competitive:
  - Less energy demand
  - Additional absorption of CO_2 -> GWP = 0,93
  - More water consumption: agriculture

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4. Inventory analysis – production processes

Type	El. en. consumption / kWh/kg	Tech. waste / %	El. en. consumption for tech. waste / kWh/kg
LDPE	0,608665	5 %	0,3413 (36,6 %)
PP-Life	1,5	na*	na*
Mater-BI	0,85787	10 %	0,5547 (40,8 %)

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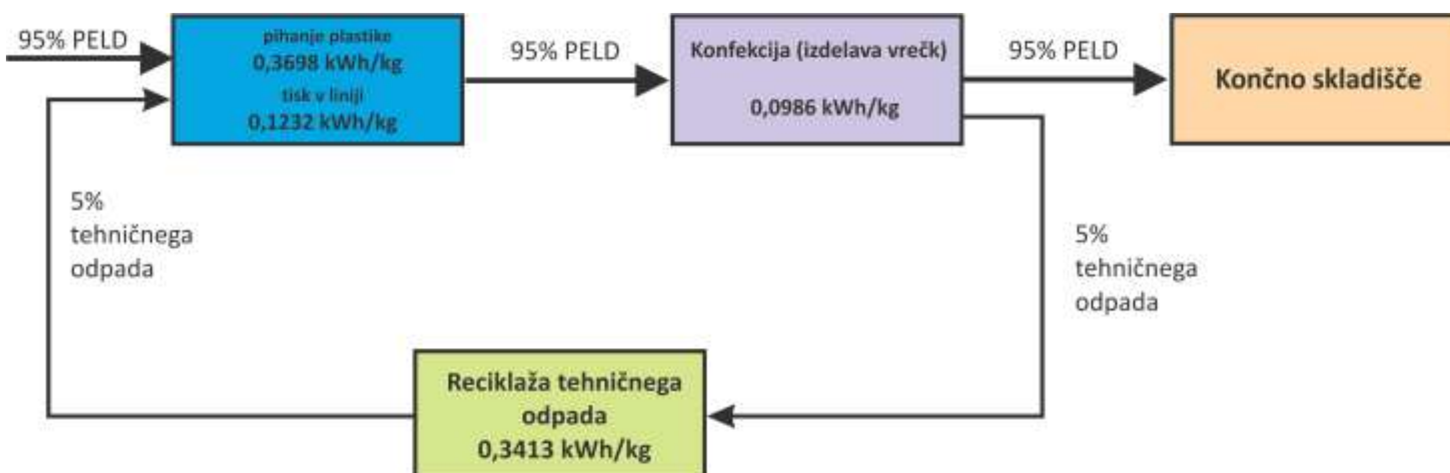

Electricity consumption in production process of LDPE bag, source: Plasta d.o.o.

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4. Inventory analysis –transport (LDPE, Mater-BI)

Bag	From	To	Type of transport	Distance
LDPE Mater-BI	LDPE (Linz, AUT)	Proizvodnja, Plasta d.o.o., Šentrupert	22 ton, EURO 5	475 km
	Mater-BI, Terni, Italija			800 km
	Valkarton, Logatec			90 km
	Plasta d.o.o.	Central storhouse Mercator d.d., LJ	9,3 ton, EURO 5 (Volvo FH 400)	70 km
	Storehouse Mercator d.d., LJ	Central storhouse Mercator d.d., Ptuj	9,3 ton, EURO 3**	41 km*
	Storehouse Mercator d.d.	Stores / Shops Mercator d.d.	9,3 ton, EURO 3**	50 km**

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4. Inventory analysis –transport (PP-Life)

Bag	From	To	Type of transport	Distance
PP-Life	Producers of PP granulate, India, Saudi Arabia, Thailand ****	Manufacturer of PP long life bags, Ho Chi Minh City	Cargo ship, overseas	6000 km
			22ton, EURO 1	50 km
	Cardboard manufacturer, Vietnam		22ton, EURO 1	20 km
	Manufacture, Ho Chi Minh City, Vietnam	Port Ho Chi Minh City, Vietnam	22 ton, EURO 1	50 km
	Port Ho Chi Minh City, Vietnam	Port Trst, Italija	Cargo ship, overseas	12.500 km
	Port Trst, Italija	Storehouse Mercator d.d., Ljubljana	15 ton, EURO 3**	95 km
	Storehouse Mercator d.d., LJ	Storehouse Mercator d.d., Ptuj	9,3 ton EURO 3**	41 km*
	Storehouse Mercator d.d.	Stores / Shops Mercator d.d.	9,3 ton, EURO 3**	50 km***

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4. Inventory analysis – End Life Scenarios

Type	Landfill	Incineration	Composting	Mech. recycling
LDPE	☑	☑		☑
PP – Life	☑	☑		☑
Mater-BI	☑	☑	☑	

Mechanical recycling:

- 50 % share: LDPE, PP-Life
- 0 % share: Mater-BI

- Include:
  - Transport (recyclate)
  - El. energy consumption – Grinding of recyclate

source: Plasta d.o.o., Vietnam, literature

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4. Inventory analysis – End Life Scenarios

Type	Landfill	Incineration	Composting	Mech. recycling
LDPE	☑	☑		☑
PP – Life	☑	☑		☑
Mater-BI	☑	☑	☑	

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Landfill of municipal solid waste, EU 27

- The use of landfill gas – environmental credits:
    - Electrical energy production

- Question!: How many landfills have this installed?

Mass: 43 % of grocery bags to landfill (EU27 data)

4. Inventory analysis – End Life Scenarios

Type	Landfill	Incineration	Composting	Mech. recycling
LDPE	☑	☑		☑
PP – Life	☑	☑		☑
Mater-BI	☑	☑	☑	

Waste incineration, EU 27

- Plastics, paper, municipal waste, biodegradable waste fraction
- Environmental credits:
  - Heat
  - Electricity
- Mass: 7 % of grocery bags to incineration (EU27 data)

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4. Inventory analysis – End Life Scenarios

Type	Landfill	Incineration	Composting	Mech. recycling
LDPE	☑	☑		☑
PP – Life	☑	☑		☑
Mater-BI	☑	☑	☑	

Industrial composting (source: literature)

- Additional burdens:
  - Transport: diesel fuel
  - Diesel/Electricity consumption in composting process: Grinding & Air supply
  - CO_2 in NH3 emissions

- NO environmental credits as in the case of landfill/incineration
- NOT suitable for agricultural

Opportunity: Credits ⇨ the case of HOME compost (Mater-BI)!

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5. Numerical model: **Mater-BI** base case

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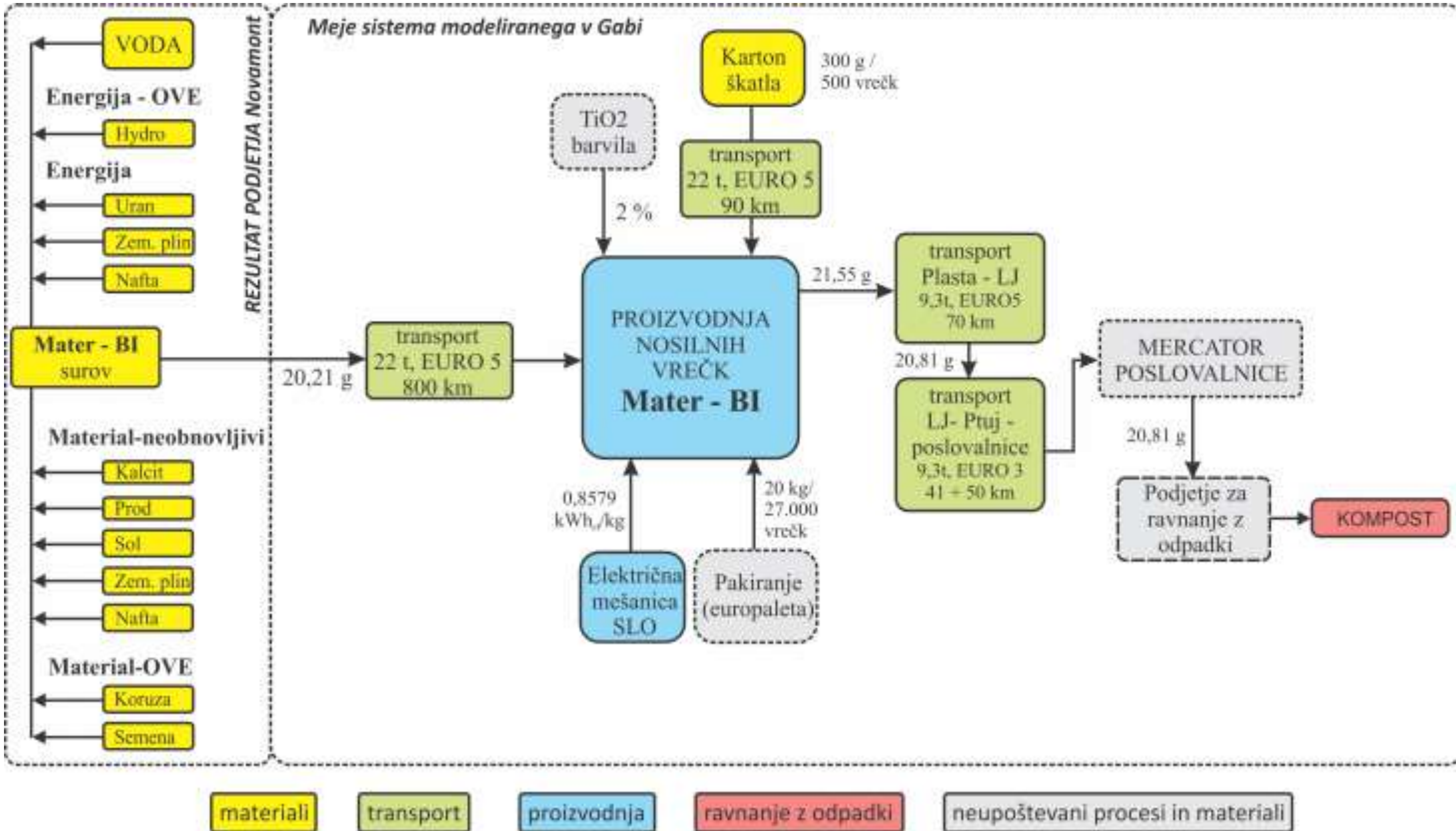

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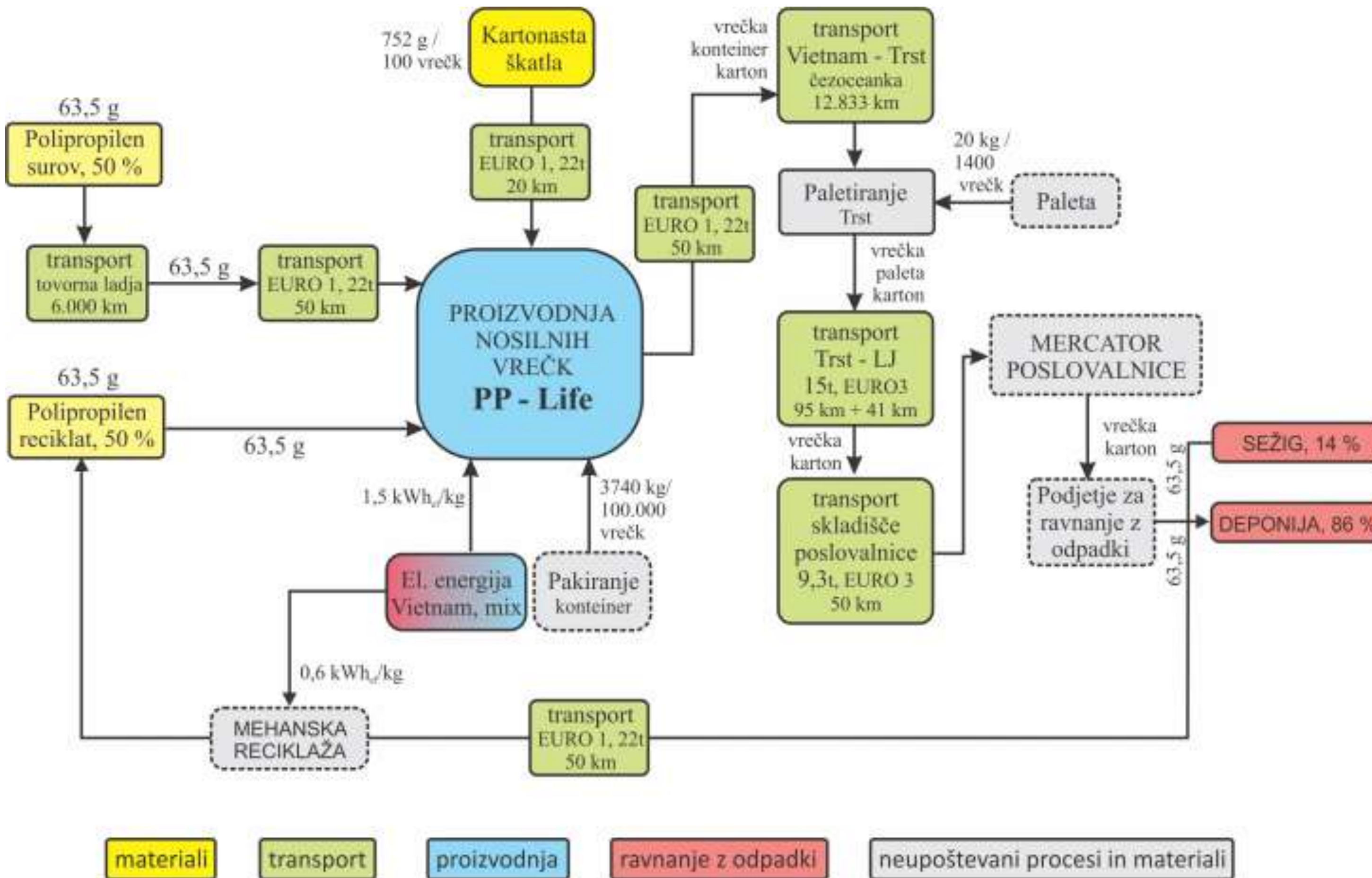
5. Numerical model: **PP-Life** base case



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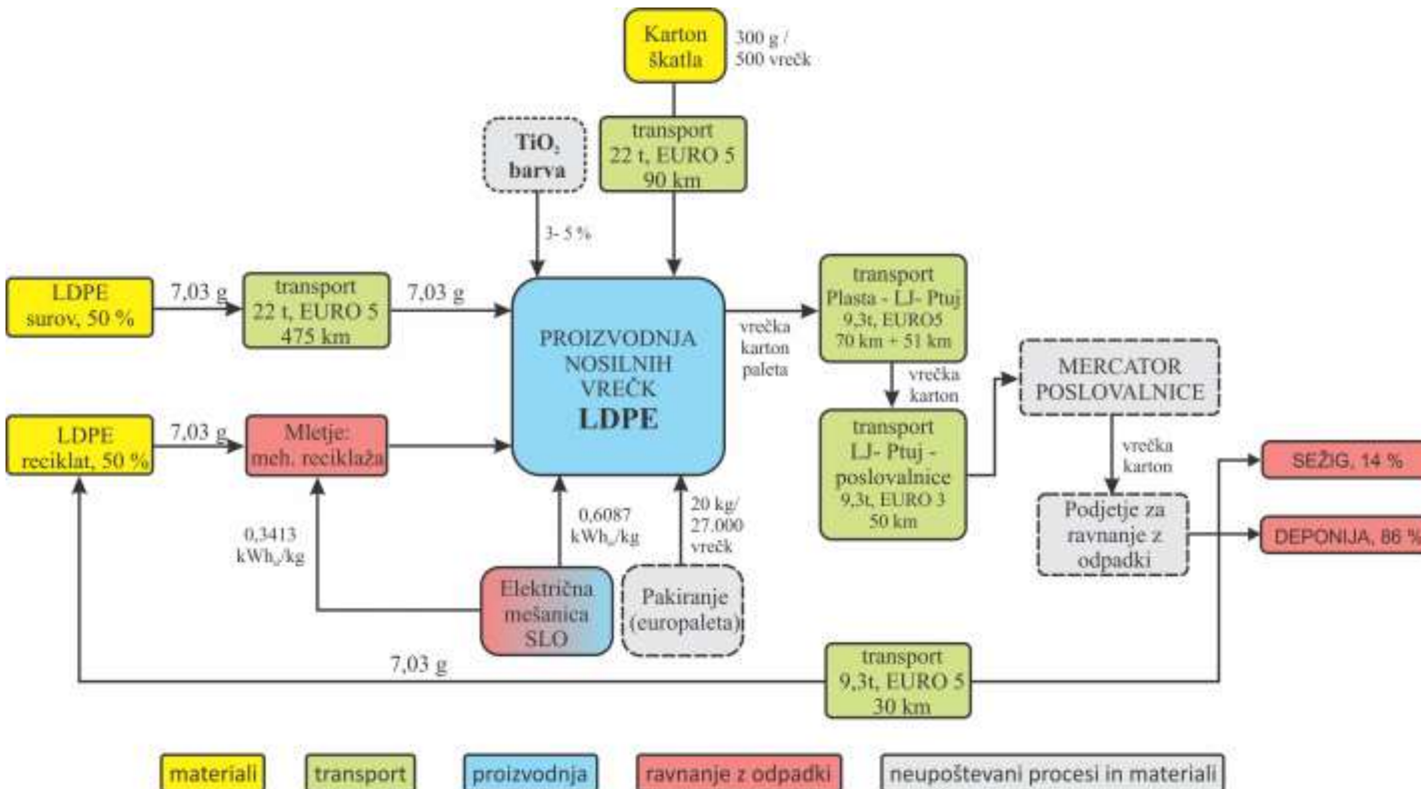
5. Numerical model: **LDPE** base case



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6. Environmental indicators (CML 2001)

- **Global warming potential (100 years), GWP / kg CO2-eq**
- Abiotic Depletion, ADP elements / kg Sb-eq
- Acidification Potential, AP / kg SO2-eq
- Eutrophication Potential, EP / kg PO4-eq
- Ozone Layer Depletion Potential, ODP steady state / kg R11-eq
- Photochem. Ozone Creation Potential, POCP / kg Eten-eq
- Primary energy demand from ren. and non ren. resources, MJ

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Greenhouse gas	CO_2 eq.
Carbon dioxide (CO_2)	1
Methane (CH_4)	25,75
Nitrogen oxide (NO_X)	296
Tetrafluoromethane	5700
Heksafluoroethane	11900
Halon 1301	6900

Global warming potential (GWP) for greenhouse gases

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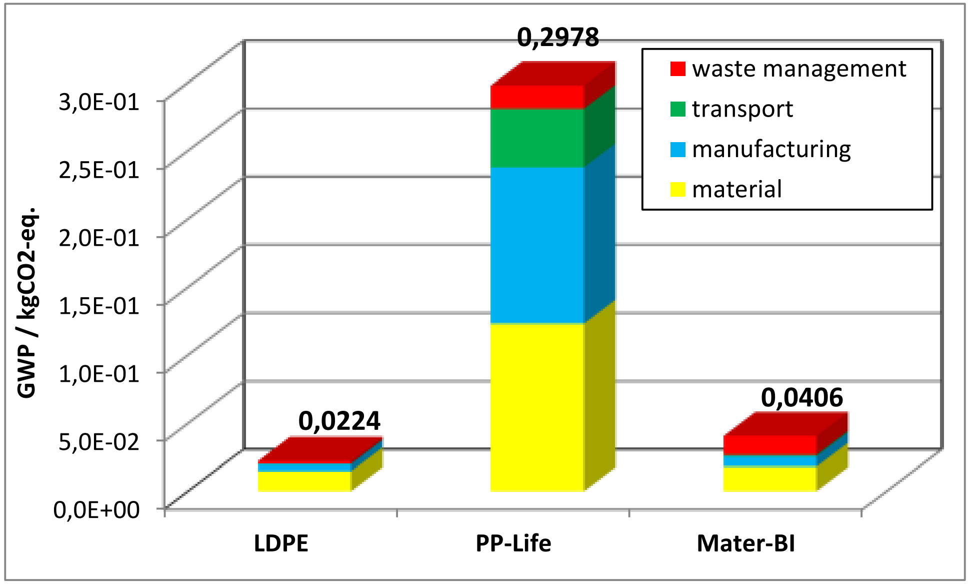
7. Results: GWP, 1 bag - functional unit

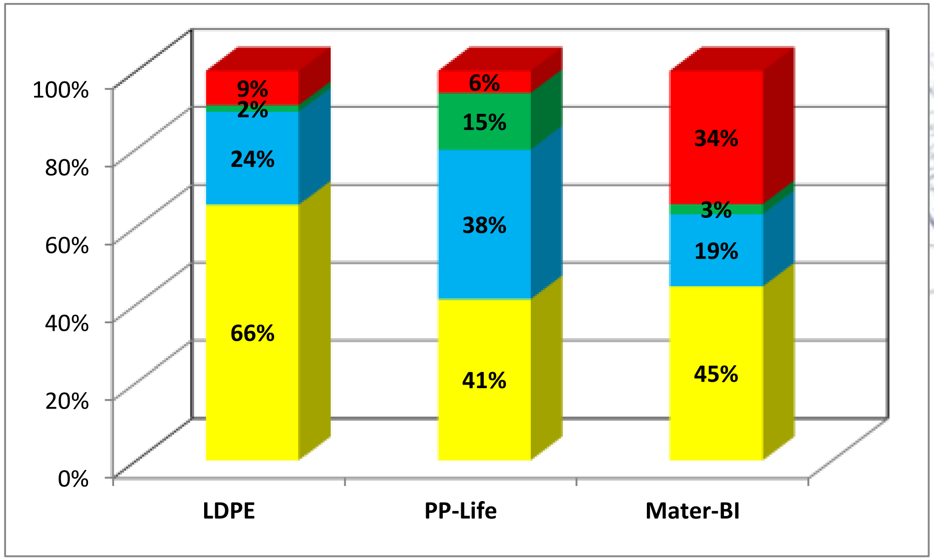


ABSOLUTE VALUE

- 1 bag
- Different masses
- Base scenarios
- Industrial composting

RELATIVE CONTRIBUTION

- Granulate production
- Bag manufacturing
- Waste management
- Transport



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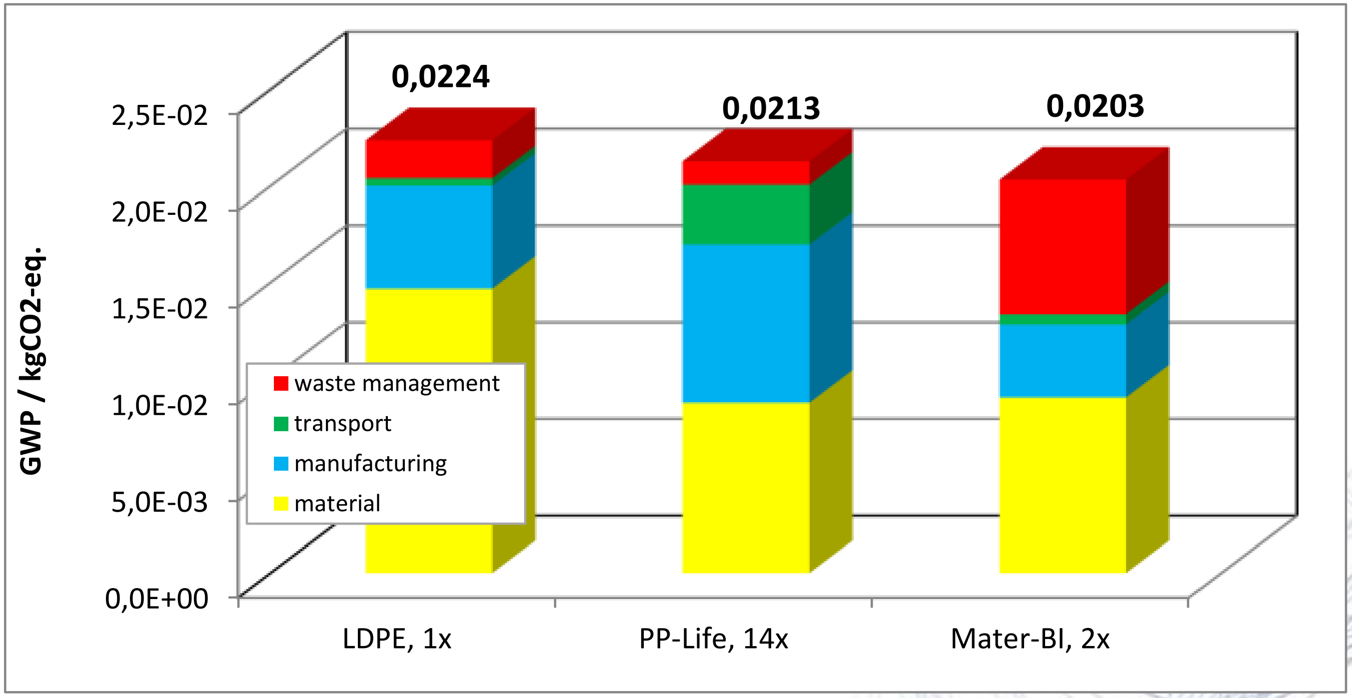
7. Results: Break-even analysis (LDPE as base)

Primary reuse of PP-Life & Mater-BI bag till GWP drops below GWP of LDPE bag



- 14x primary reuse of PP-Life
- 2x primary reuse of Mater-BI

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7. Results: Environmental indicators (Mater – BI)

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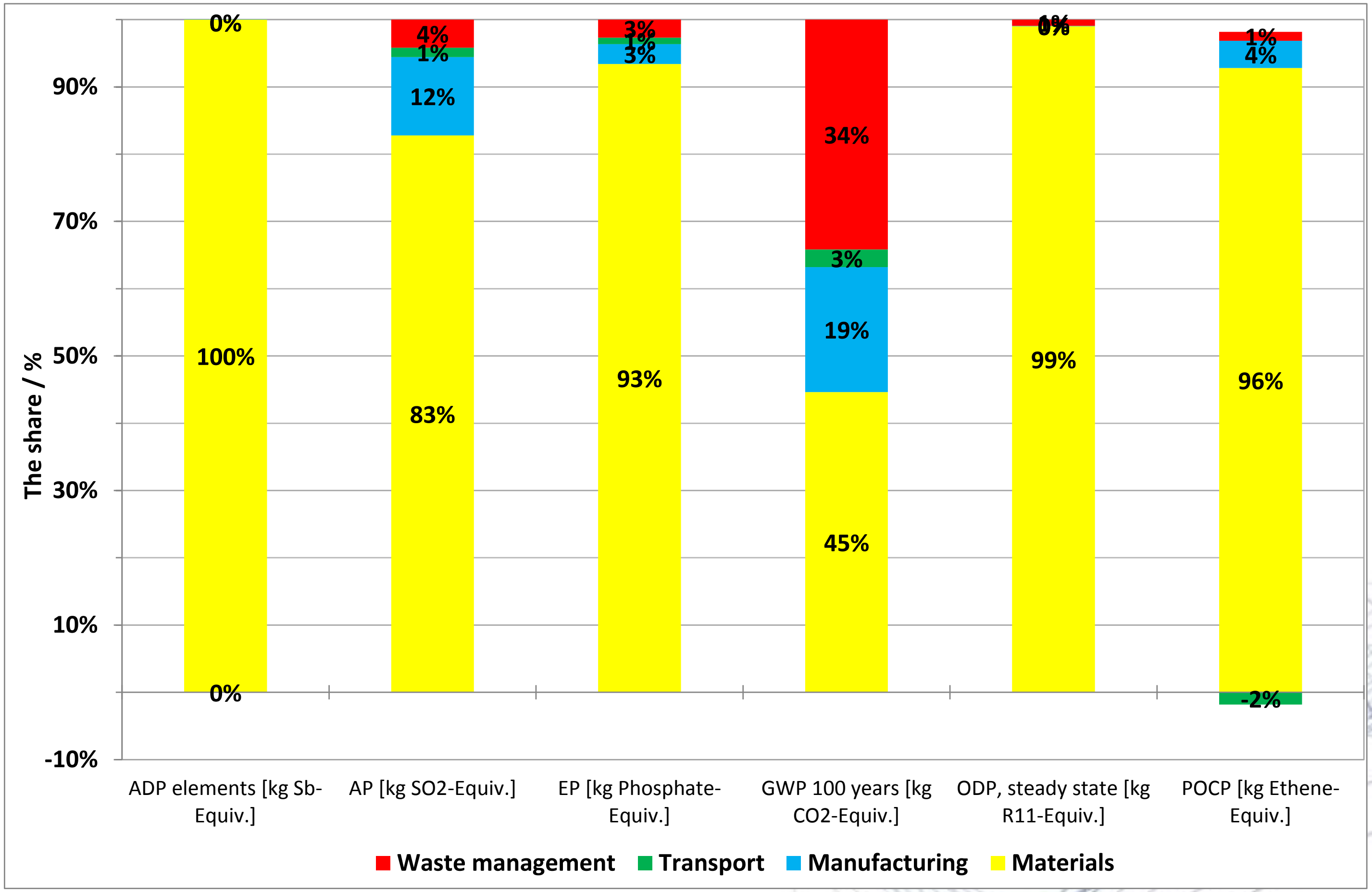

Relative contribution of life cycle phases for Mater-BI bag

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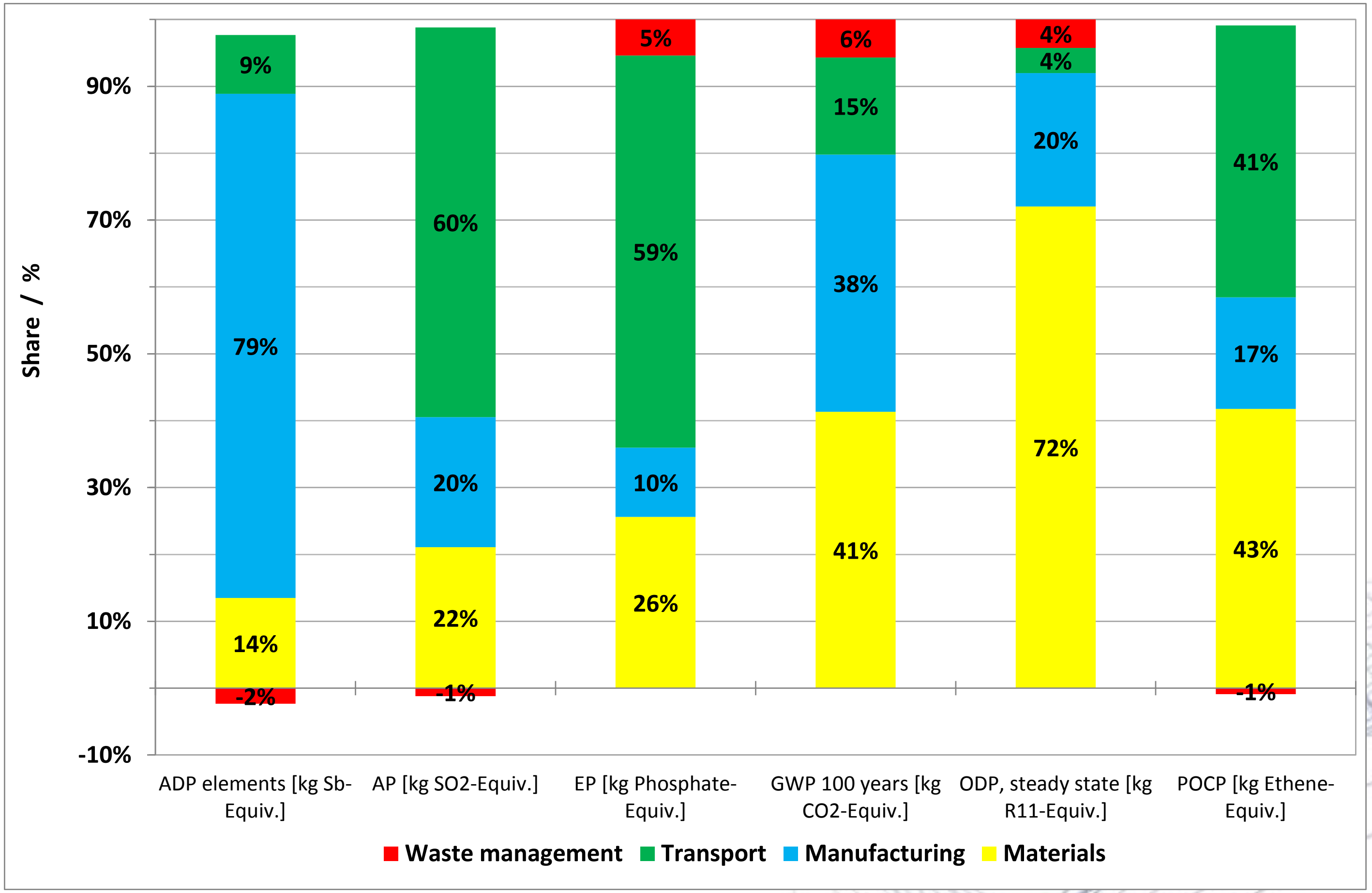
7. Results: Environmental indicators (PP-Life)



Relative contribution of life cycle phases for PP-Life bag

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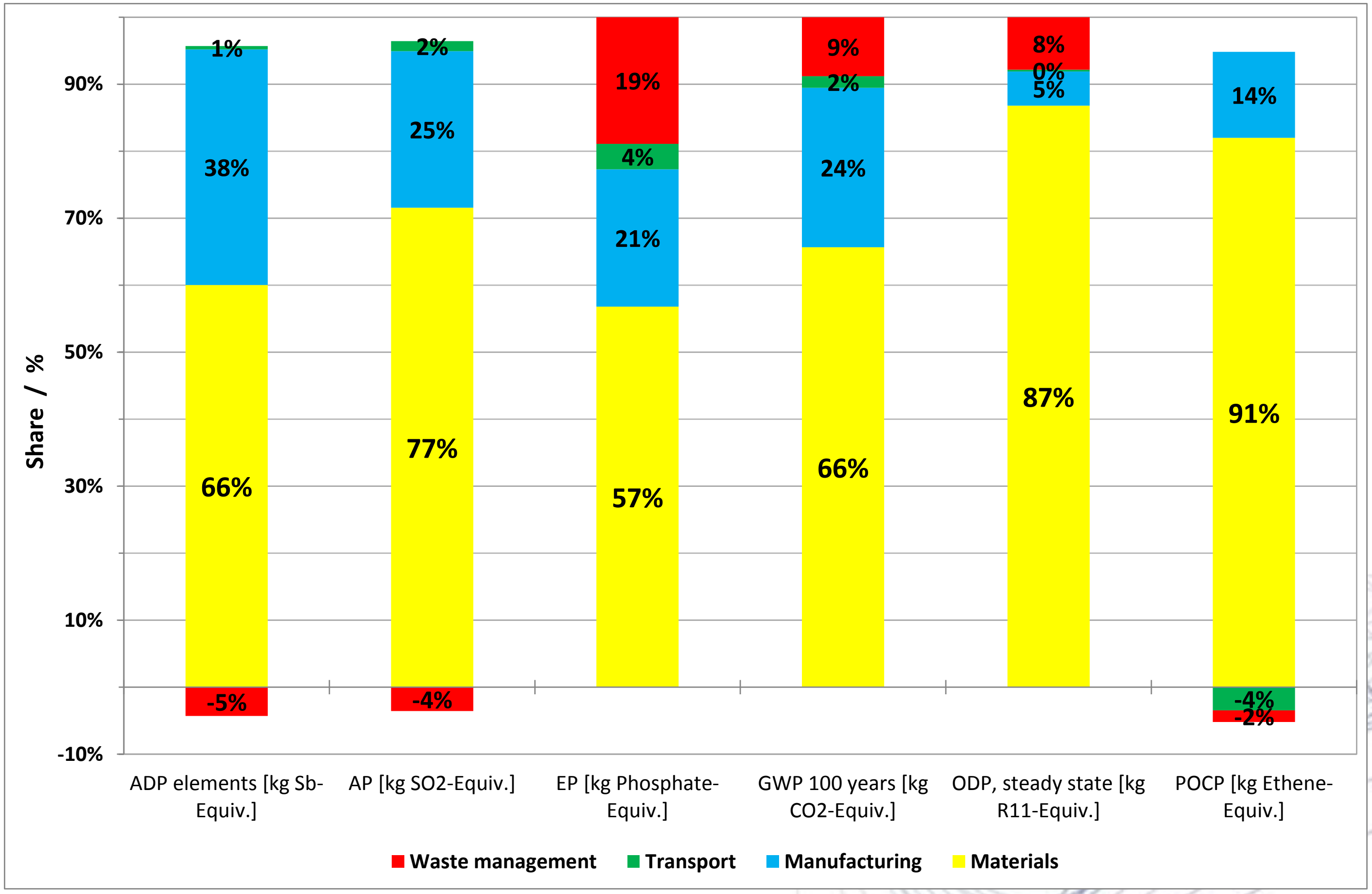
7. Results: Environmental indicators (LDPE)



Relative contribution of life cycle phases for LDPE bag

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7. Results: Indicators for 1 bag

	LDPE	PP-Life	Mater-BI
	14,8 g	**127 g**	**20,21 g**
Abiotic Depletion, ADP elements / kg Sb-Eq.	2,76E-09	3,83E-08	**4,12E-04**
Acidification Potential, AP / kg SO2-Eq.	7,53E-05	**1,88E-03**	2,22E-04
Eutrophication Potential, EP / kg Phosphate-Eq.	7,02E-06	**2,03E-04**	6,89E-05
Global Warming Potential, GWP 100 let / kg CO2-Eq.	2,24E-02	**2,79E-01**	4,06E-02
Ozone Layer Depletion Potential, ODP, stacionarno / kg R11-Eq.	5,60E-11	8,17E-10	**6,87E-09**
Photochem. Ozone Creation Potential, POCP / kg Eten-Eq.	9,55E-06	**1,41E-04**	4,52E-05
Primary energy demand from ren. and non ren. resources [MJ/kos]	**0,662**	**7,34**	**1,52**

- Mass influence: 14,8 g – 127 g – 20,2 g
- Mater-BI vs. LDPE bag: Mater-BI inferior to LDPE
- 37 % more mass of granulate
- Influence of industry composting (relatively 34 %):
  - NO credits,
  - Energy consumption (electricity, diesel)

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7. Results: Mass equality - 20 g

	LDPE	PP	MaterBI
Abiotic Depletion (ADP elements) [kg Sb-Eq.]	4,40E-09	9,23E-10	4,16E-04
Acidification Potential (AP) [kg SO2-Eq.]	1,60E-04	1,25E-04	1,84E-04
Eutrophication Potential (EP) [kg Phosphate-Eq.]	1,01E-05	1,49E-05	6,46E-05
Global Warming Potential (GWP 100 years) [kg CO2-Eq.]	4,25E-02	3,98E-02	1,86E-02
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Eq.]	0,00E+00	0,00E+00	6,82E-09
Photochemical Ozone Creation Potential (POCP) [kg Eten-Eq.]	2,42E-05	1,86E-05	4,38E-05
Primary energy demand, [MJ]	1,59	1,50	1,32
Water consumption, [kg]	0,90	0,81	4,66

- Theoretical approach;
- Equality / Competitiveness of Mater-BI bag!

Opportunity

- Implementation of agricultural composting ⇨ credits!
- 34 % of overall burden (GWP) comes from industry composting

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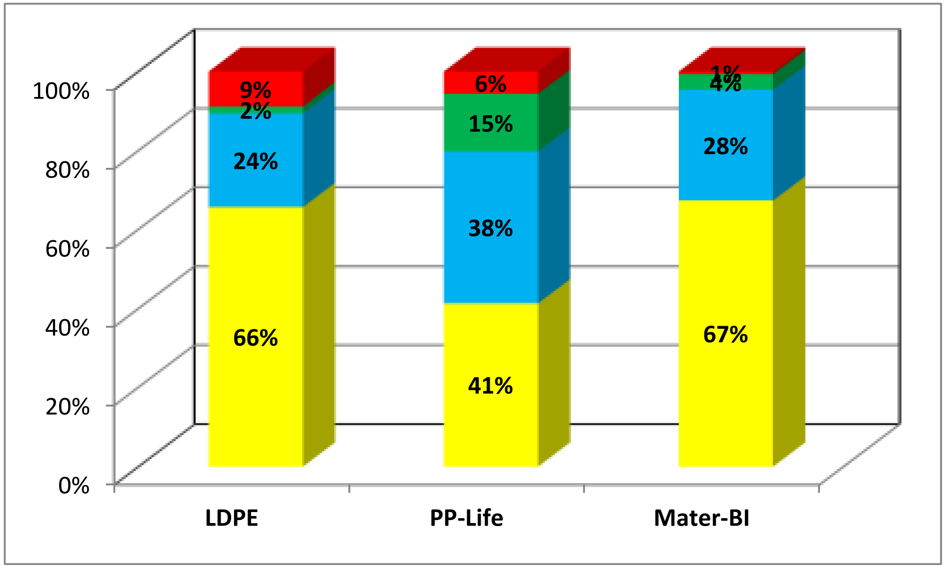
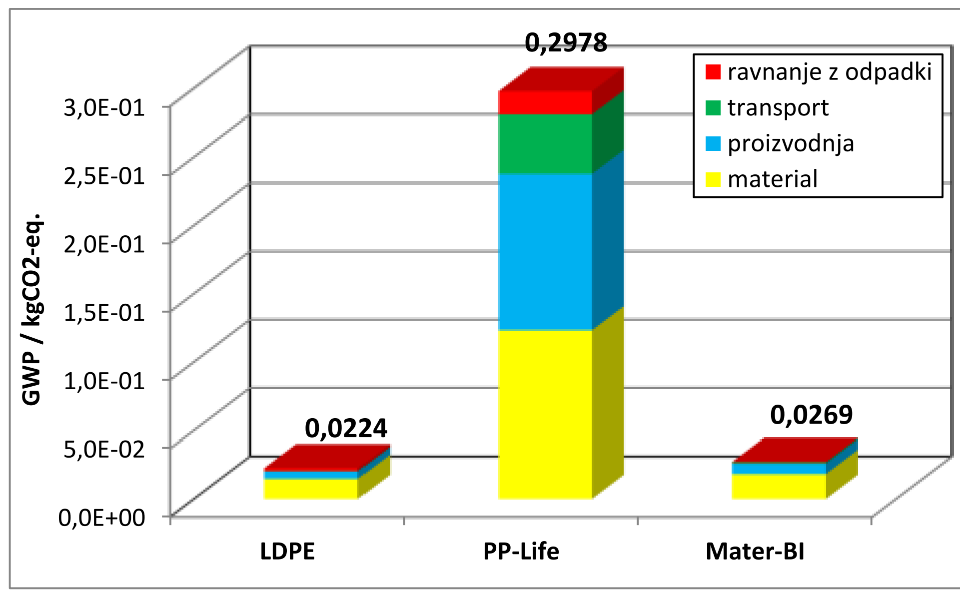
7. Results: GWP of Mater-BI (potential)



- NO industrial composting influence.
- **Equal to LDPE!**



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7. Results: Primary & Secondary REUSE

Primary REUSE (All bags)

- As many as possible.
- Proportional reduction of environmental burdens.

Secondary reuse (LDPE, Mater-BI)

- As bin linears
- Separate LCA model
  - Same manufacturing process
  - 50 % material mass
  - 1x use – end life: landfill of municipal waste

REDUCTION of environ. burdens in average for 40 % LDPE
REDUCTION of environ. burdens in average for 46 % Mater-BI

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7. Results: Waste management scenarios

	LDPE	PP-LIFE	Mater-BI
Base scenario**	50% recycling 7 % incineration 43 % landfill	50% recycling 7 % incineration 43 % landfill	100% composting*
100 % mech. recycling	☑	☑	
Landfill – ALL	☑	☑	☑
Incineration - ALL	☑	☑	☑

* not for agriculture

** EU average

All scenario analysis are done as comparison to base scenario.

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7. Results: Waste management scenario **LDPE**

LDPE bag	BASE - 50 % recycling - 7 % inciner. - 43 % landfill	- 0 % recycling - 14 % inciner. - 86 % landfill		- 100 % recycling - 0 % inciner. - 0 % landfill		- 50 % recycling - 0 % inciner. - 50 % landfill		- 50 % recycling - 50 % inciner. - 0 % landfill	
ADP elements / kg Sb-Eq.	2,76E-09	3,98E-09	+44%	1,55E-09	-44%	2,99E-09	+8%	1,34E-09	-51%
AP / kg SO2-Eq.	7,53E-05	1,25E-04	+66%	2,57E-05	-66%	7,99E-05	+6%	4,73E-05	-37%
EP / kg Phosphate-Eq.	7,02E-06	1,15E-05	+64%	2,44E-06	-65%	7,82E-06	+11%	2,12E-06	-70%
GWP 100 y. / kg CO2-Eq.	2,24E-02	3,80E-02	+70%	6,59E-03	-71%	2,12E-02	-5%	2,98E-02	33%
ODP / kg R11-Eq.	5,60E-11	5,94E-11	+6%	5,22E-11	-7%	5,37E-11	-4%	7,03E-11	26%
POCP / kg Eten-Eq.	9,55E-06	1,75E-05	+83%	1,65E-06	-83%	1,00E-05	+5%	6,57E-06	-31%
Energy consumption / MJ	0,66	1,16	+76%	0,16	-76%	0,71	+7%	0,39	-41%

Mechanical recycling ⇨ lowers burdens significantly

Landfill ⇨ all indicators are worse (not GWP? Why: time)

Incineration:

all indicators are better ⇨ Why? (credits)

GWP excluded ⇨ reason? (emissions)

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7. Results: Waste management scenario **Mater-BI**

Mater-BI	**BASE** 0 % recycling 0 % incineration 0 % landfill 100 % compost	0 % recycling 0 % incineration 100 % landfill 0 % compost		0 % Reciklaža 100 % sežig 0 % deponija 0 % kompost	
ADP elements / kg Sb-Eq.	4,12E-04	4,12E-04	**0%**	4,12E-04	**0%**
AP / kg SO2-Eq.	2,22E-04	2,16E-04	**-3%**	2,14E-04	**-3%**
EP / kg Phosphate-Eq.	6,89E-05	1,03E-04	**49%**	6,80E-05	**-1%**
GWP 100 y. / kg CO2-Eq.	0,04064	0,04602	**13%**	0,03755	**-8%**
ODP / kg R11-Eq.	6,87E-09	6,81E-09	**-1%**	6,87E-09	**0%**
POCP / kg Eten-Eq.	4,52E-05	4,96E-05	**10%**	4,44E-05	**-2%**
Energy consumption / MJ	1,52	1,51	**-1%**	1,50	**-1%**

BASE ⇨ industrial composting

Landfill

- Credits are included (electricity)
- Some indicators are worsen, some stay the same

Incineration

- Credits are included (electricity, heat)
- In the range of industrial composting

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7. Results:Actual bags consumption in Slovenia (9,2 bags/month household)

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Type	LDPE	PP-Life	Mater-BI
Consumption	552	1	552

5 years – life expectancy of long life PP bag

5 years	LDPE	PP-Life	Mater-BI
ADP elements / kg Sb-Eq.	1,52E-06	**4,42E-08**	2,27E-01
AP / kg SO2-Eq.	4,16E-02	**1,94E-03**	1,23E-01
EP / kg Phosphate-Eq.	3,87E-03	**2,07E-04**	3,81E-02
GWP 100 y. / kg CO2-Eq.	1,23E+01	**2,98E-01**	2,24E+01
ODP / kg R11-Eq.	3,09E-08	**8,45E-10**	3,79E-06
POCP / kg Eten-Eq.	5,27E-03	**1,45E-04**	2,50E-02
Energy consumption / MJ	365	**7**	839

Superiority of PP-Life: 50 –100x differnece in most indicators

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8. Conclusions

MANUFACTURERS

Enlarge the share of **recycylate**

Energetic **efficiency** of manufacturing :

- Less electricity;
- Heat consumption;

!

CONSUMERS: Which bag to pick?

PP Life advantages:

- 14x primary reuse ⇨ reaches the GWP of LDPE
- In 5 years (lifetime) ⇨ 41x less GWP of LDPE

?

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8. Conclusions

CONSUMERS: REUSE!

Primary: proportional reduction of burdens

Secondary: reduction of burdens in both cases

⇨ more for LDPE, bit less for Mater-BI

!

CONSUMERS: How to properly dispose the bag?

LDPE & PP-Life: yellow litter bin!

Mater-BI: 1st alternative = home compost

⇨ avoid fertilizers production

⇨ reduction of burdens

2st alternative = brown litter bin (industrial comp.)

NOT IN YELLOW LITTER BIN!

!

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8. Conclusions

CONSUMERS – Inappropriate waste management

LDPE in black linear bin: 7 % incensement of burdens

PP-Life black linear bin: 3 % incensement of burdens

Mater-BI in black linear bin: GWP +13 %, 0 % < others < +49 %

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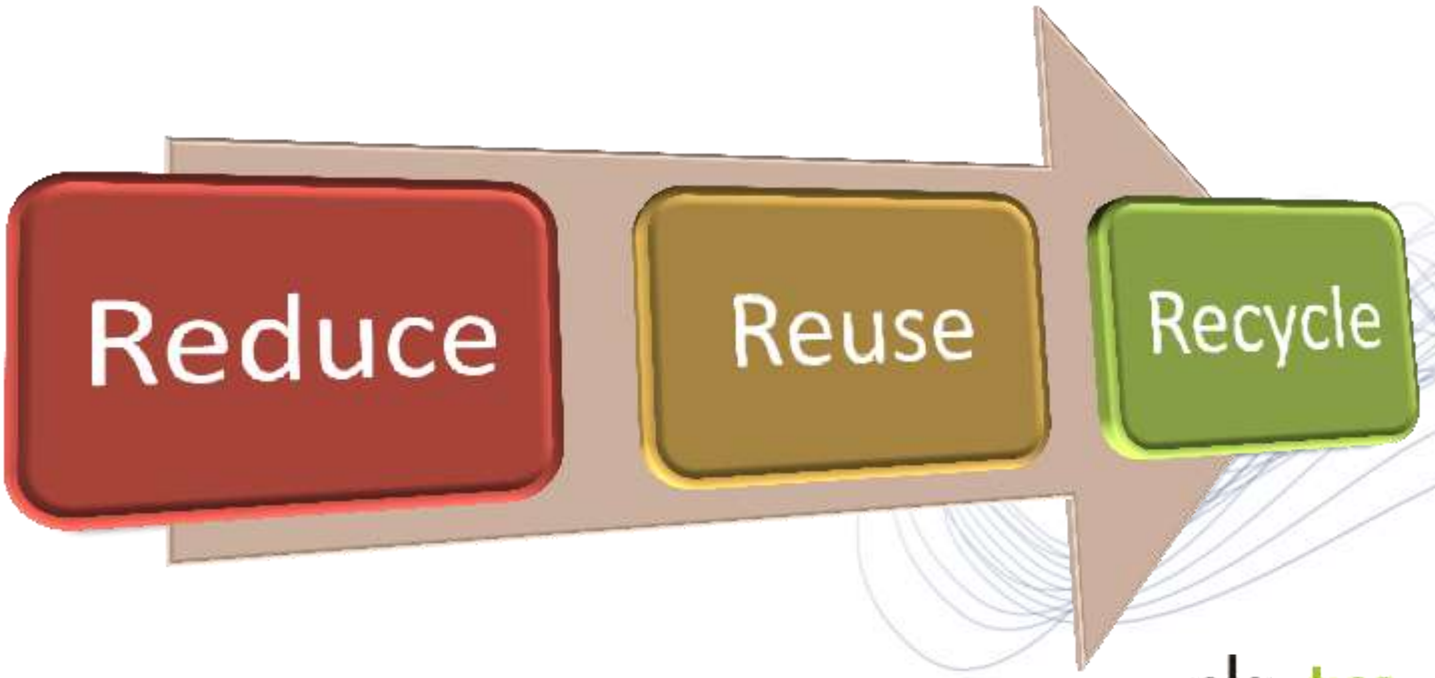
9. Basic recommendations: 3R

Reduction of VIRGIN materials use (technology)



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10. Further research

1. Exclude all environmental credits:
   - Landfill
   - Incineration

2. Compare Mater-BI with PLA:
   Polylactic acid (PLA) (based on literature, modified PE)

next steps

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Relativity of results

140 m

1 LDPE bag in whole LIFE CYCLE

=

140 m average car drive

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